The method of preparing the specimens is then briefly described. Observations were conducted principally on white mice, which were injected with the author's prussian blue fluid immediately after death *. The paper concludes with the following summary of the most important facts elucidated in the inquiry :—

1. That nerve-fibres in muscle and in many other tissues, if not in all, may be traced into, and are directly continuous with, a network formed of oval nuclei and intermediate fibres.

2. That the organs by which nerves are brought into relation with other textures, and the agents concerned in the development of nerves and the formation of new fibres, are the little oval bodies or nuclei which are present in considerable number in the terminal ramifications of all nerves. A great number of these bodies is associated with exalted nervous action, while, when they are sparingly found, we may infer that the nervous phenomena are only imperfectly manifested.

3. That every elementary fibre of striped muscle is abundantly supplied with nerves, and that the fibres of some muscles receive a much larger supply than others.

4. That the nerves lie, with the capillaries, external to, but in close contact with, the sarcolemma. They often cross the muscular fibre at right angles, so that one nerve-fibre may influence a great number of elementary muscular fibres. There is no evidence of their penetrating into the interior of the fibre.

The paper is illustrated with drawings, most of them magnified 700 diameters.

VII. "On the Effects produced by Freezing on the Physiological Properties of Muscles." By Michael Foster, B.A., M.D. Lond. Communicated by Dr. Sharpey, Sec. R.S. Received June 4, 1860.

The influence of cold upon animal life has been studied chiefly (as for example in reference to the phenomena of hybernation) at such degrees of temperature only as are insufficient to freeze the tissues. In cases of actual freezing, attention seems for the most part to have

* The Microscope in its Application to practical Medicine, p. 63.

been directed to the organism as a whole, with a view of determining the question whether an animal apparently frozen to death could be revived. The older writers* often allude to the revival of frozen insects as a familiar fact. Rudolphi† states that frozen Filariæ are brought to life upon thawing. Franklin found frozen fishes revive on thawing; yet John Hunter‡ never succeeded in restoring the animals he had frozen.

One element of uncertainty in such experiments (in those on vertebrate animals at least) is the difficulty of making sure that the heart itself is frozen, without interfering with the expected result. In the experiments of a later observer, Duméril§, it seems clear that the hearts of the frogs he froze and recovered, were not frozen, though the intestines were.

Spallanzani‖ seems to have been the only one among the older writers who studied the freezing of muscles removed from the influence of the general blood-current, and that only in an indirect way. He revived irritability in the muscles of frogs, toads, and salamanders, which, after immersion for several hours in snow, had become rigid, "presque gelées," and gave no contraction upon being stimulated. But he states that muscles frozen by a more intense cold lost their irritability for ever. His means of stimulation were chiefly mechanical. There seems fair reason to suspect that the muscles which recovered their irritability were but partially frozen, had but partially lost their irritability, and would have exhibited a decided contraction when treated by those modifications of the galvanic stimulus which the modern physiologist has at his command. Spallanzani¶, in another work, states that frozen snails died.

Among later writers, the only authority I can find is Schiff, who states**, "A sufficiently intense degree of cold will render muscles rigid, and yet so that they can be revived. It is not clearly made out though whether this is accompanied by any contraction." And again, p. 46, "Frogs' muscles bear freezing without irretrievable loss of irritability for a longer time than they will exposure to that

* Reaumur, Whytt, Blumenbach, Spallanzani.
† Histor. Entoz. t. ii. p. 62.
‡ Works by Palmer, vol. iv. p. 131.
§ Annales des Sciences Naturelles, 1852, vol. xvii. p. 7.
‖ Opuscules, tr. Senebier, vol. i. (ch. vi.) p. 113.
¶ Letters on Respiration. ** Lehrb. s. 44.

degree of heat which resembles frost in depriving them of irritability."

Having myself made some experiments on this subject, I venture to lay them before the Society.

Two methods were adopted to freeze the muscles. In most instances I securely enclosed them in little bags of thin gutta percha, and so buried them in a mixture of salt and snow, or pounded ice. At other times I suspended them in pure olive oil, contained in a small vessel surrounded by the freezing mixture; having previously ascertained that immersion for two hours at least in the same oil, at an ordinary temperature, had no injurious effect upon muscular irritability.

The results I came to were as follows:—

1. Completely frozen muscles are not irritable to the strongest stimulus we possess.

2. Muscles which have been frozen for a short time only (five or ten minutes at the longest) may regain their irritability on being thawed.

3. Muscles which have been frozen for more than ten minutes never regain their irritability.

The loss of irritability seems to be due more to the occurrence of freezing than to any mere fall of temperature. For although the irritability does diminish with the fall of temperature, and markedly so when the freezing-point of water is neared, yet the great loss and final extinction takes place only when the tissue itself is frozen.

I know of no method of treating a muscle so as to lower the freezing-point of the water contained in its tissue, without so injuring it as to render such a procedure useless for the present purpose.

In order that the irritability of any muscle should wholly disappear, the muscle must be wholly frozen. A muscle may be in great part frozen, and yet capable of producing a movement when stimulated, by the contraction of the unfrozen part.

The passage into the frozen state is accompanied by no contraction. Frogs' limbs freeze exactly in the same position which they were previously maintaining; and when the individual muscles were frozen singly, I was unable to satisfy myself of the occurrence of any contraction. Nor could I assure myself of the advent of any physio-

logical rigidity distinguishable from the physical frozen state. The reaction of frozen muscle, as indicated by litmus paper, is neutral or faintly alkaline, thus differing from recently dead muscles.

It is not the mere rigidity of the frozen muscle which mechanically, so to speak, prevents contraction, for irritability does not at once and fully return upon thawing. An interval of time may with care be detected in most cases, during which the muscle is already thawed, but yet not irritable; and irritability returns gradually.

There is no exact relation between the duration of the frozen state and the duration and amount of the revived irritability. It is not the case that a muscle frozen three minutes regains twice as much irritability, or remains afterwards irritable twice as long as a muscle frozen for six minutes. The frost does not progressively exhaust as it were a given store, leaving, according as the operation is shorter or longer, more or less residue to be manifested when the muscle is thawed.

The amount of revived irritability will depend in great measure on the treatment the muscles experience when first thawed. The receipt then of a slight shock, which afterwards it will bear with impunity, if not with advantage, may be sufficient to throw it back altogether into death.

Nor is the present a case of mere stoppage of the wheels of life, which, when once set in motion again, go on as well as before. Muscles once frozen, however kindly treated, eventually die sooner than those left untouched. There has been in the act of freezing a partial exhaustion of their vital forces.

I ascertained, by section, that muscles which afterwards regained their irritability were frozen throughout. Hence the revival of irritability cannot be supposed to depend upon any part having been left unfrozen. Nor, in muscles partially frozen, did the unfrozen parts seem to have any influence over the life of the frozen parts.

In muscles which have been well frozen, the fibres are more readily separable from each other, and divisible into fibrillæ, than in those which die an ordinary death. Under the microscope, the fibres are clouded and more opake than usual, the transverse striæ generally invisible, and in some cases the whole sarcous tissue seems to be converted into a confused amorphous mass, lying loose in a sarcolemma, which is more strongly defined than usual.

But these histological appearances have but little to do with the physiological phenomena. A muscle may be frozen so as to lose all irritability, and yet preserve its natural appearance. Two muscles may be frozen so that both shall scarcely have a fibre that is not more opake than natural and that has not lost its striæ,—both, in short, shall be affected anatomically, as far as we can at present tell, to the same degree, and yet one will live and the other is dead.

In muscles which never regained their irritability, the act of thawing was accompanied by the onset of a peculiar rigor, which differed from the "rigor mortis," and resembled the "rigor caloris" in being an active contraction, *i. e.* in producing a movement. The hind leg of a frog, when rigor mortis comes on, retains the position it previously had, whether of flexion or extension. Powerful excitation of the spinal cord or ischial plexus produces extreme extension. Plunging into boiling water brings the flexed leg to extreme extension. If the leg be killed by frost in a flexed condition, it will when thawed assume gradually the position of extreme extension: so muscles, frozen singly, shorten when thawed. This contraction is never seen in muscles destined to regain their irritability. I have seen it come on in a muscle which had been frozen for three hours: it is a sure sign of death. This contraction continues after the production of the movement as a peculiar rigidity, which vanishes only when the softening from decomposition becomes apparent.

The effect of low temperature on the frog's heart is very peculiar. There is a great diminution in the rate of rhythm, and very marked increase in the duration of each systole, so that sometimes the heart is frozen in a tetanic beat, as it were. I have never seen a frozen heart resume its beat when thawed; but I have often seen one part of the ventricle still beating while another part was frozen quite hard.

Similar results were obtained by freezing the muscles of leeches and snails. Frozen for a short time they recovered their irritability, for a longer time they died.

In the latter animals, not only was mere irritability recovered, but I have seen snails, which I had every reason, by examining the state of snails of the same size frozen under exactly the same conditions, to believe had been frozen throughout, regain voluntary motion, and crawl about with extended horns as if nothing had happened. Their

slowly altered blood does not seem to lose its virtues by having passed into a state of ice.

In the frog, the return of irritability is favoured by connexion with the general circulation. A frog was secured with its hind legs in a freezing mixture, the brain and spinal cord having been removed. In a few minutes the legs were frozen stiff, and had lost all irritability. After being frozen half an hour they were thawed. Irritability returned.

Nerves, too, like muscles, lose their excitability when frozen, and, like them, may regain it on being thawed if they have not been frozen too long. I have always found a greater difficulty in recovering nerves than muscles.

One very curious thing is this, that, as Eckard states*, when nerves are frozen, the muscles to which they are distributed are thrown into contractions; and yet when muscles themselves are frozen, there is not only no tetanic spasm, but not necessarily even the smallest quivering.

VIII. "On the alleged Sugar-forming Function of the Liver." By Frederick W. Pavy, M.D. Communicated by Dr. Sharpey, Sec. R.S. Received June 21, 1860.

(Abstract.)

This communication is an abridgement of a paper bearing the same title presented by the author to the Royal Society in 1858, with some additional matter, since disclosed by his experimental investigations.

He first shows, by analyses, that although the blood collected from the right side of the heart after death, as was formerly done, affords an abundant indication of the presence of sugar, yet that when it is removed from the same part by catheterism during life, it is found to contain but a trace of the saccharine principle. Inferences, therefore, that have been drawn of the *ante-mortem* state from *post-mortem* examinations must be abandoned as erroneous.

The heart excised instantaneously after sudden killing, contains blood as free from sugar as it is during life.

* Eckard, Zeitschrf. Rat. Med. vol. x. (1851).